Life at the cutting edge

Biologists, planetary scientists and engineers have gathered in southern Spain to test a robotic drill. They hope some day to probe for life beneath the surface of Mars. **Jenny Hogan** investigates.

"Okay, we're at the surface," a voice calls across the tent. "Can someone hit the 'yes' button?" In the centre of a makeshift laboratory, sweltering beneath the Spanish sun, people cluster anxiously around a robotic drill. Its silver arm draws up from the deep hole it has made in the dirt. Hitting the 'yes' button will trigger the drill to release its cargo, and reveal whether it has managed to bore material from metres beneath our feet.

"Have we got a core?" asks Howard Cannon, an engineer from NASA's Ames Research Center in California. Peering into the end of the instrument, he spots a plug of red mud, some 7 centimetres long. This is good news. The drill is a prototype for an instrument that might one day be sent to Mars. It's Cannon's job to see if he can get the drill to work here on Earth.

A team of mission scientists is pretending that this drill, and the precious core it carries, is located on Mars. The drill is equipped with scientific instruments to search for signs of life in the dirt. So, for the team, extracting this chunk of red earth could be a step towards finding out whether life lurks beneath the sterile surface of Mars.

The drilling technologies being tested here, or others like it, may one day travel to the red planet aboard European Space Agency or NASA missions (see box, overleaf). Although the martian surface is too cold, dry and drenched in radiation for anything to survive above ground, past life forms could have taken refuge underground, some scientists think.

Data from the swarm of spacecraft currently roaming over and orbiting Mars have identified some possible spots where surface life may once have thrived. "We do our best to pick the sweet cherries, the prime candidates for life," says James Dohm, a planetary geologist at the University of Arizona, Tucson. "But eventually we have to have subsurface analysis."

The Spanish project is headed by planetary scientist Carol Stoker of the Ames Research Center, a veteran of previous Mars missions, and focuses on the unusual geochemical environment of Spain's Rio Tinto region.

To a visitor, the landscape looks little like barren Mars. The drill sits at the edge of an old

mining pit that is surrounded by pine trees. A lake of red-hued water lies below, and groves of orange trees stretch out in the distance. Local authorities recognize the beauty of the place; they erected a sturdy stone picnic bench for tourists — right on one of the team's preferred drilling sites.

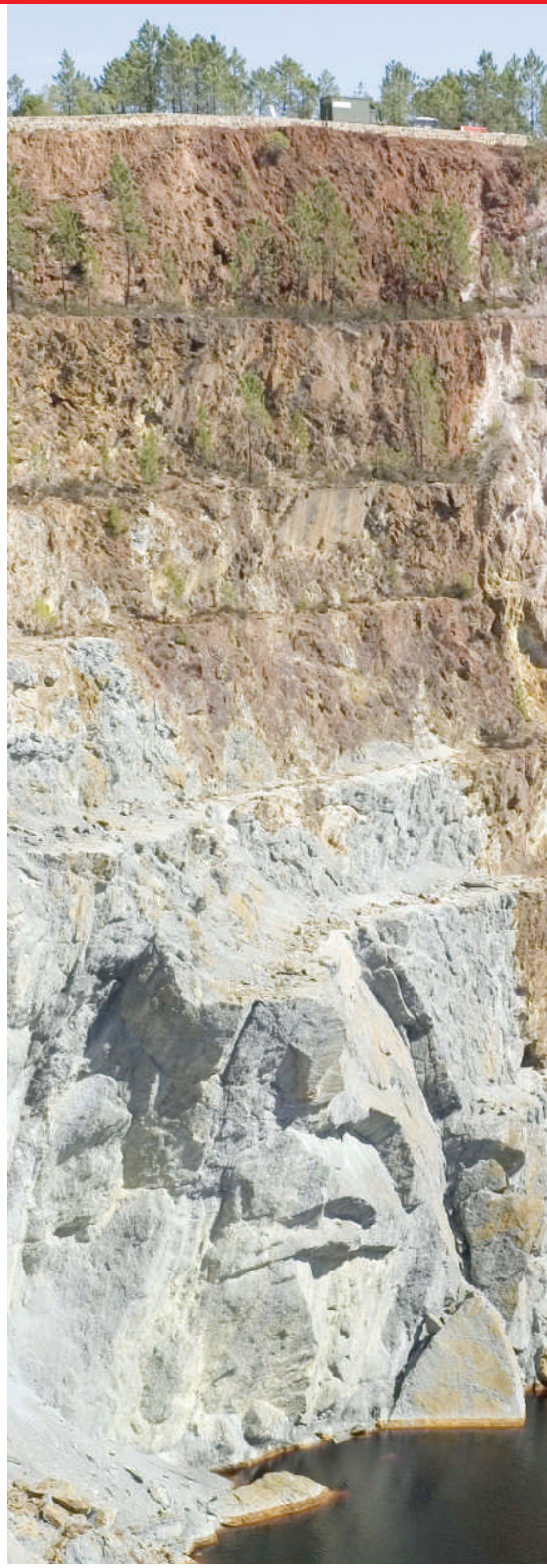
Hostile habitat

But it's underground, in the rocks from which the scenery is carved, that the Rio Tinto region may be most like Mars. A hardy microbial world inhabits the acidic waters of the Tinto river. This is what astrobiologists dream of finding in the subsurface of other worlds.

Microbiologist Ricardo Amils, of the Autonomous University of Madrid, a member of the science team, has studied the area for years and once gave Stoker an enthusiastic tour. Her imagination was fired by the idea of an underground ecosystem. "I'm not sure it struck him as a really good planetary analogue, but it did me," she says. Thus, the Mars Analog Research and Technology Experiment (MARTE) was born.

In 2004, the project's second year, it got a huge boost from data flowing back from NASA's Mars Exploration Rovers, Spirit and Opportunity. The rovers identified minerals on the surface of Mars, including the sulphate jarosite, which suggested that, when it existed, martian water was salty and acidic[1]. These are just the kind of conditions found at Rio Tinto[2].

Planetary scientists, with their study subjects so far out of reach, have long scoured Earth for otherworldly environments. For years, Mars researchers have been studying the life forms that eke out an existence in the Atacama Desert of Chile or in the cold, parched Dry Valleys of Antarctica. One group is exploring ice-bound communities of bacteria in a frozen volcano on Svalbard, the arctic archipelago off the coast of Norway. Some, in an effort to understand the martian atmosphere, are studying the dust devils whipped up in



E. JAMES/NASA AMES

A robotic drill that might one day be used on Mars is tested out at the edge of an old mining pit in Rio Tinto.

J. HOGAN; E. JAMES/NASA AMES

The analysis of cores extracted by a drill (left) may shed light on the nature of the scum in Rio Tinto's springs.

Nevada's Eldorado Valley. Others put rovers through their paces in rock-strewn deserts.

Michael Meyer, NASA's lead scientist for Mars, says it is important to study as many of these places as possible. "We don't want to get too far ahead of ourselves in predicting what Mars is like and expend all our energy on one site," he says. But Rio Tinto, he says, is a good place to include.

The Tinto river gets its unique chemistry from the Iberian Pyrite Belt, a vast deposit of sulphide minerals tens of kilometres wide that runs for about 250 kilometres through southern Spain and Portugal. These minerals were laid down when the region was under water; at the site of a hydrothermal vent, deep-seated volcanism forced hot water, rich with dissolved chemicals, through cracks in Earth's crust.

Bottom dwellers

Although the Tinto river is naturally acidic and loaded with heavy metals, mining has exacerbated these characteristics[3]. For 5,000 years, locals mined the deposit for heavy metals, notably copper. Around Nerva, the Spanish town where the MARTE team is based, the hills are scarred by open pits and abandoned mining equipment. The acidity, in turn, led to other metals in the rocks dissolving, including the iron that gives the Tinto river its distinctive red colour and name.

Amils thinks that some of the river's heavy metals are extracted from their ores by bacteria living inside the rocks. This unique biosphere, he reckons, is powered by sulphur and iron. He says the river could serve as "an exhaust for a giant underground bioreactor". Although Amils and other biologists have quantified the microbial ecosystem at the surface[4,5], the MARTE project has been their first opportunity to go underground.

While Cannon is operating the robotic drill in the stuffy tent, Stoker and other members of the MARTE science team are enjoying the air-conditioning of the ultra-modern Center for Astrobiology building outside Madrid. Olga Prieto Ballesteros, head of the remote-operations team, marks the new core on a whiteboard.

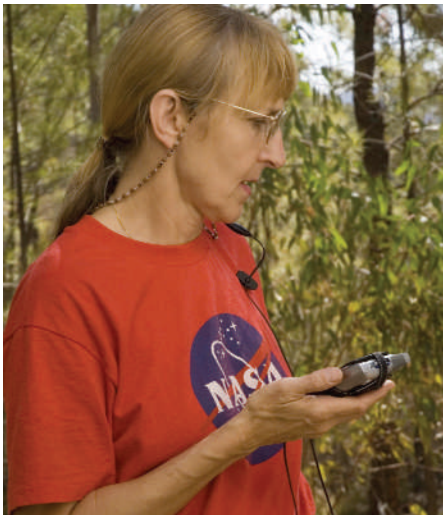
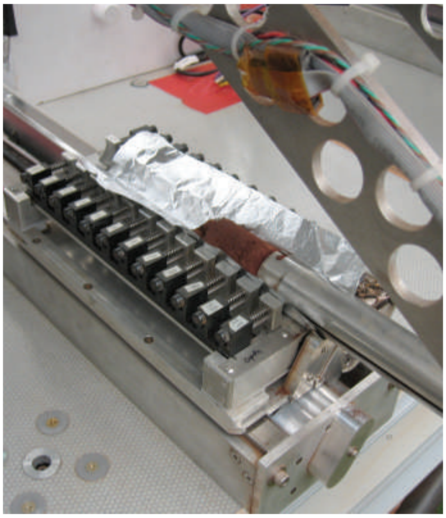
"The MARTE project has advanced the date the technology might be ready for a drilling mission on Mars." — Carol Stoker

A satellite dish is relaying data from the drill site at a rate of 50 megabytes per day — roughly equivalent to the speed at which a spacecraft on Mars might be able to transmit information to Earth. The remote science team can access data from the drill's instruments, including pictures of the core and the output of an imaging spectrograph that helps identify the minerals present.

This year, the team's month of drilling nets them a hole just over 6 metres deep. Geologists may snicker to call this deep drilling, but Stoker calls it an impressive accomplishment for a robotic drill loaded with science instruments. "Nothing like this has been done before," she says.

If the remote researchers spot an interesting part of a core, they can get the robotic drill to subsample it, and pass the sample through sophisticated life-detection systems. The team can also instruct the drill to lower a camera into the borehole, to inspect the surrounding walls. In this case, the team knows there's a good chance that life could exist in the borehole. But it pretends otherwise. "If we see a filament in the rock, we know it's a root," says Ballesteros. But the root is sampled and tested before they conclude that it is life.

Of the samples analysed already, "we have detected life in cores three and five", says a team biologist. The results come from the signs-of-life detector (SOLID) instrument, which uses a protein microarray to look for molecules that are characteristic of life. Astrobiologists routinely cite such techniques

E. JAMES/NASA AMES; J. HOGAN

Carol Stoker (left) hopes that the drill technology developed by her team could be adapted for Mars.

when they talk about searching for life on other planets[6].

Back at Rio Tinto, the drill is working hard to bring up new samples. It is designed to run with minimum human intervention. "Right now, we're sitting here doing nothing," says Cannon. "But every once in a while something will fail and we have to step in."

Terrestrial drillers would usually select their drill bit to suit the rock, and change the speed and power depending on the conditions they encounter. In contrast, a robotic drill on Mars is stuck on its own with just one drill bit and one technique.

Another huge challenge is cleaning out the hole, to prevent the drill from clogging. On Earth some kind of fluid can be pumped down the drill shaft to remove the cuttings. This isn't feasible on Mars, so the drill built for the MARTE by New York-based Honeybee Robotics operates dry.

Lone worker

A screw around the outside of the drill bit is meant to carry the debris to the surface, but it keeps getting encrusted with muck. The team has resorted to vacuuming it clean. Red dust coats everything, including the laptops running the robot.

As the robot ejects a new core, a researcher lunges inside the rig to catch it on sterilized tin foil. Moments later, she dabs a cotton bud over the core, swabbing material to analyse for ATP, the energy-rich molecule that acts as fuel for life on Earth. Samples destined for the SOLID instrument are rushed from the drilling tent to an air-conditioned vehicle next door, because the tent is too hot for the instrument to operate properly.

Despite such difficulties, the MARTE team remains optimistic. They had not set out to solve every drilling and scientific question in 30 days. The point of the simulation, they say, was to see what works and what needs to be worked on. "We've got a lot of work to do, but this is a first step," says Cannon. Stoker agrees, and is enthusiastic about what they have learned: "This project has advanced the date the technology might be ready for a drilling mission — there's no doubt about that." Still, the project's US$6-million funding runs out this year, and it's unclear whether the drilling rig will get another outing.

Biologists will be back at the Rio Tinto site, regardless. They may have drilled deep holes, but Amils says they've only scratched the surface of understanding how this ecosystem works. During a tour of some springs near the source of the Tinto, he notes the murky red, brown and white deposits in the water and on the surrounding rocks. Amils labels many of the oozy, lumpy patches 'scum', a euphemism for 'difficult to identify'. Some are minerals, some are life. Most are not yet classified.

Todd Stevens, his colleague and an expert in geomicrobiology from Portland State University in Oregon, sums it up: "We have a lot of work to do to understand the interactions of the rocks and microbes on Earth before we can do it on other planets." ■

Jenny Hogan is a reporter with *Nature*.

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FIRST DRILL ON MARS

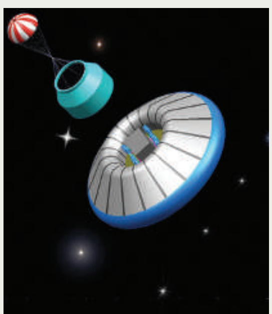
The first drill to reach Mars might be launched in 2011 by the European Space Agency (ESA), on a mission called ExoMars.

If approved at a December minister-level meeting, ExoMars would include a small rover carrying a lightweight drill. It would be capable of boring 2 metres into the martian surface. That would be deep enough, scientists hope, for it to get through the oxidized surface layer and into relatively unaltered martian soils.

It's certainly deeper than any sampling tool has ever gone before. The Viking landers scratched up some topsoil in the 1970s, and today's Mars rovers grind small holes in surface rocks. Only the Beagle probe, presumed to have crashed on landing in 2003, carried the technology to get underground, and its 'mole' never got a chance to burrow.

ESA already has experience in putting drills aboard spacecraft. Last March, it launched the cometary mission Rosetta, which carries a drill to pierce more than 20 centimetres into Comet Churyumov-Gerasimenko.

For the ExoMars project, ESA is considering two possible designs. One, named DeeDri, is being developed by the group that provided Rosetta's drill, headed by the Italian Space Agency. The other, CanaDrill, is being sponsored by the Canadian Space Agency.



Artist's view of the ExoMars descent module.

ESA

CanaDrill could have the first shot at getting into space, if it is selected for NASA's unmanned lunar lander, details of which were announced last month. The mission could launch as early as 2010, to search for water in the shadowy craters near the Moon's south pole.

With NASA's new push to send astronauts to the Moon and Mars, the agency is more interested than ever in nurturing drilling technologies. Drills could help astronauts reach natural resources, such as underground water reservoirs if they exist.

The challenge is making drills lightweight and energy-efficient enough to fly, says David Beaty, a former exploration geologist in the oil industry who now works for NASA's Jet Propulsion Laboratory in Pasadena, California. He is organizing a 'drill-off' that will take place next February, when a handful of companies developing robotic drills will test their machines at Idaho Falls.

Competitors will be charged to build a drill that weighs no more than 40 kilograms, digs 20 metres deep, and runs off the power of a lightbulb.